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EFFECTS OF POPULATION AGING AND URBAN DISPERSION ON THE USE OF URBAN TRANSPORT IN THE FUTURE

by

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ABSTRACT

An extensive analysis of data from four four-year interval Origin-Destination surveys was conducted and revealed the factors influencing urban mobility behaviour in Montreal.

Firstly, the following demographic factors affecting urban transit in the territory have changed greatly over the 1970 decade : age composition, population sprawl in suburban areas, growing number of households, continuous increase in women's participation in the workforce. Secondly, household size, population aging, car ownership and evolving individual mobility for certain groups seem to be the most significant variables explaining modal split.

Forecasting public transport usage for medium or long-term horizons (5 to 15 years) needs a modeling framework which reflects and reacts to the observed socio-demographic trends. A model formulation based on a categorization into "cohorts" (age, sex groups) is illustrated. This enables the following topics to be addressed : an analysis of the evolution of specific mobility phenomena in view of temporal and spatial transferability, and the use of a time-series forecasting model to predict transit usage in the future.

Introduction

Large scale Origin-Destination surveys, in the 1970s, have been less than popular in the transportation planning community, except, perhaps, in Montreal. In a very systematic way, since 1970, the Montreal Urban Community Transit Commission (5) has executed four large regional O/D surveys by telephone interview, on an average sampling of about 5 percent. This huge database describes the mobility of the population in terms of spatialized trip characteristics (some 1500 O/D zones), socio-economic attributes (sex, age, car ownership) and travel attributes (modes, trip purposes, bus routes, etc...); the following statistics illustrate the scope of the surveys:

year	area(km2)	sampling	population	households	trip records
1970	1 289	3.78%	2 574 467	752 461	198 988
1974	2 331	4.78%	2 824 257	897 081	264 789
1978	2 331	5.31%	2 954 185	1 031 975	305 244
1982	3 341	6.98%	2 895 899	1 071 305	491 805

This unique database can be used to investigate numerous hypotheses underlying traditional trip generation and modal split models. It is generally recognized that the expansion of travel behaviour by households, makes it difficult to forecast public transit usage based on aggregate factors.

This paper addresses two general topics: global temporal trends in personal mobility and related factors, and specific mobility trends related to spatial segmentation following the development of urban sprawl. Finally, using these findings, the application of a time-series model is illustrated.

GLOBAL MOBILITY TRENDS FROM 1970 TO 1982-- MONTREAL CASE:

The consistency of the methodology used in the four aforementioned surveys enables us to derive some robust results, from a statistical standpoint. In terms of the major

phenomena which are worthy of interest, Montreal is similar to many other North-American metropolitan regions. The main trends concern the reduction in households size, population aging and the continuous increase in car ownwership. The study territory is illustrated in figure 1.

Household size spatial distribution

The Montreal region includes nearly 50 per cent of the population of the province of Quebec. Globally, the population may be considered as stable, but composition and spatial distribution have undergone major changes. Average household size has decreased steadily from 3.42 to 2.7 (rate of 2% per year); the annual rate of decrease reached a maximum value of 2.6% for the CBD, where we find an absolute minimum of 2.24 persons per household in 1982. Figure 2 shows the general trend for 8 large urban and suburban sectors.

Population aging

Population aging is reflected by the relative weights of senior citizen and youth groups. Figure 3 shows respective percentages of 5.4% and 33.7% in 1970 transformed to very different values in 1982: 9.4% and 24.0%. The so-called active group (age 18-64) is significantly more preponderant in 1982.

Car ownership and general mobility

Car ownwership, on a per capita basis, increases continuously increase with some levelling around 1982. This phenomenon reflects the effects of the recent economic recession (fig. 4a). Figure 4b shows a recent sharp increase in personal mobility, expressed in terms of the number of trips -(excluding returns home)- per capita on an average weekday.

Over the 12-year period, the increase in the total number of trips is accompanied by a shift in the mix of trip purposes (fig.5). The proportion of work, study and shopping trips is largely decreasing to the benefit of leisure and personal affairs.

Another general trend concerns the proportional usage of transit. Unquestionably, modal split has decreased, but, in absolute terms, transit usage has been maintained (at great expense, with a greatly increased supply). Modal split has deteriorated more in suburban areas, as illustrated by Figure 6.

In summary, this crude analysis is sufficient to confirm the usual intuitions about the temporal and spatial non-stationarity of urban travel behaviour. These observations contradict hypotheses concerning constant trip rates (Bussière (4)) and constant travel budgets (Zahavi (11)). Detailed analyses are necessary to explain more subtle dimensions of mobility.

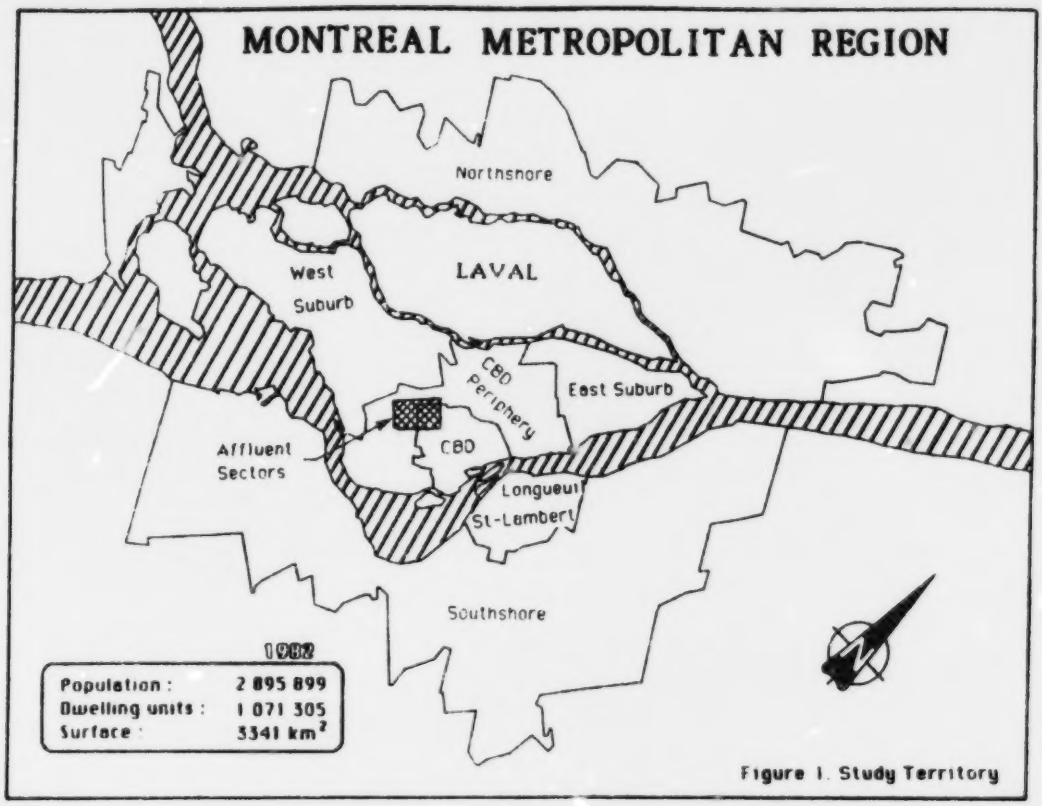


Figure 1. Study Territory

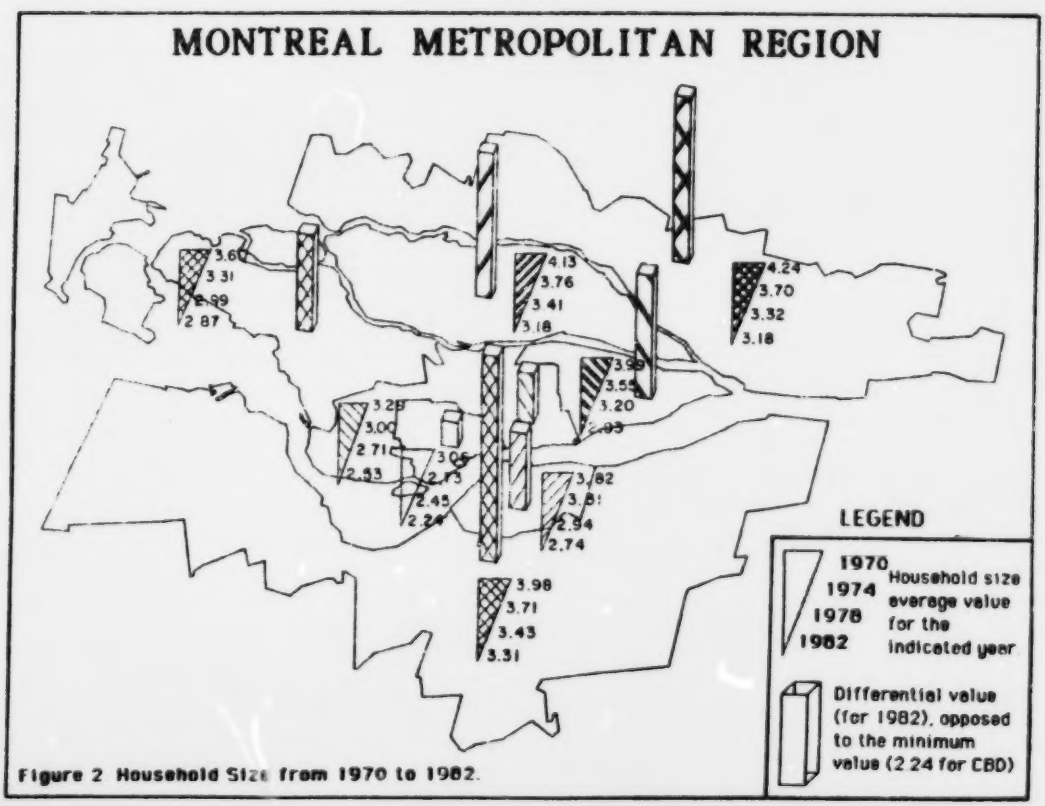


Figure 2 Household Size from 1970 to 1982.

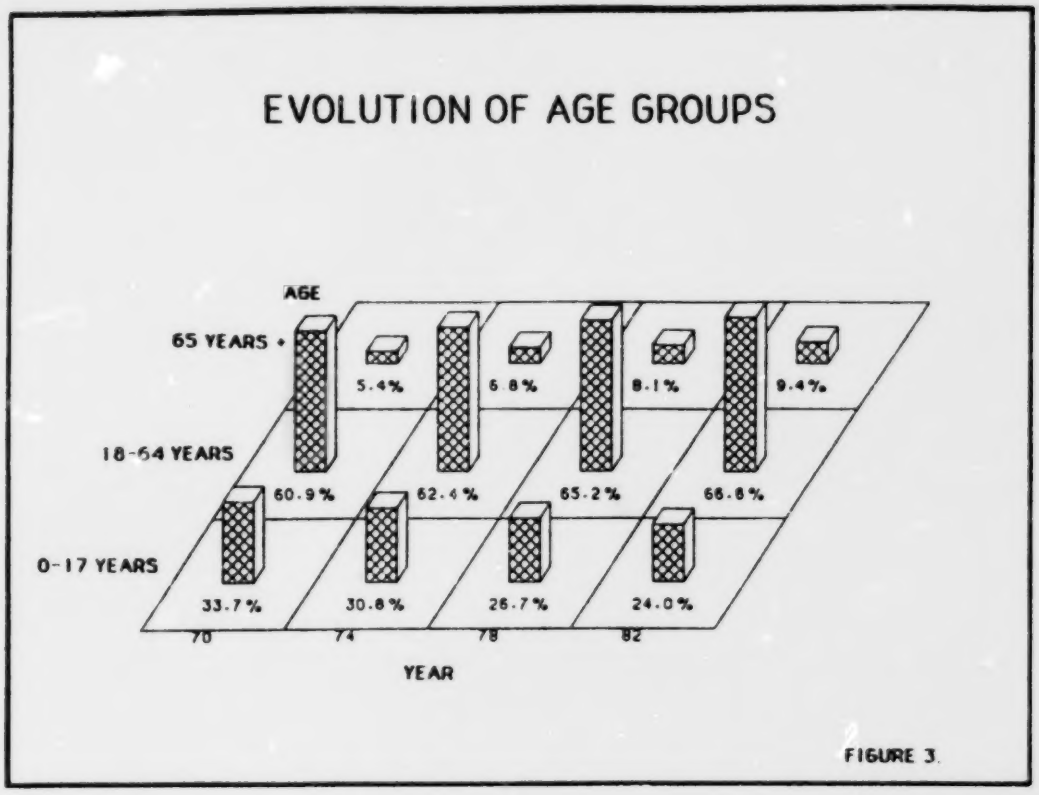
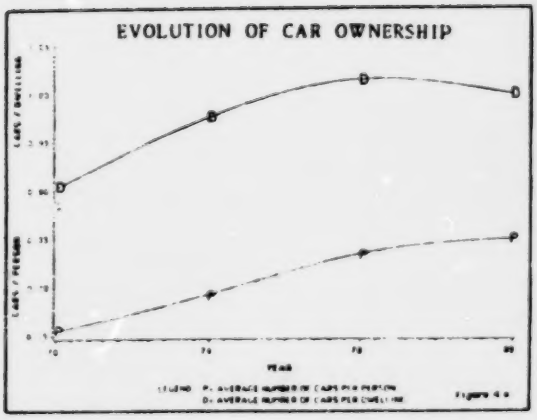
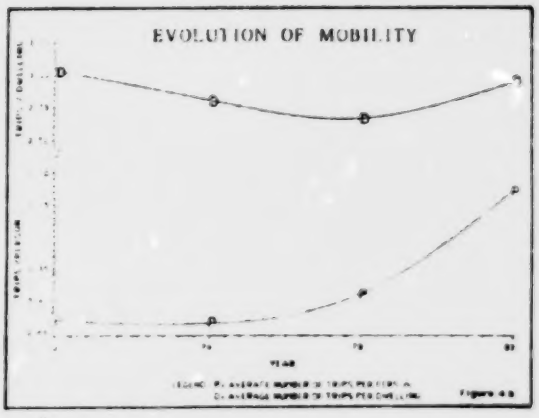

EVOLUTION OF AGE GROUPS
AGE
65 YEARS +
18-64 YEARS
0-17 YEARS
5.4%
6.8%
8.1%
9.4%
60.9%
62.4%
65.2%
66.8%
33.7%
30.8%
28.7%
24.0%
70
74
78
82
YEAR

FIGURE 3.


EVOLUTION OF CAR OWNERSHIP


EVOLUTION OF MOBILITY

YEAR	PURPOSES				
	WORK	STUDY	SHOPPING	LEISURE	OTHER
1970	40.65%	30.77%	11.17%	7.82%	9.60%
1974	42.36%	26.68%	11.76%	4.93%	12.28%
1978	41.39%	24.77%	12.43%	7.76%	13.65%
1982	35.08%	23.65%	9.39%	14.97%	16.91%

FIGURE 5. EVOLUTION OF TRIP PURPOSES

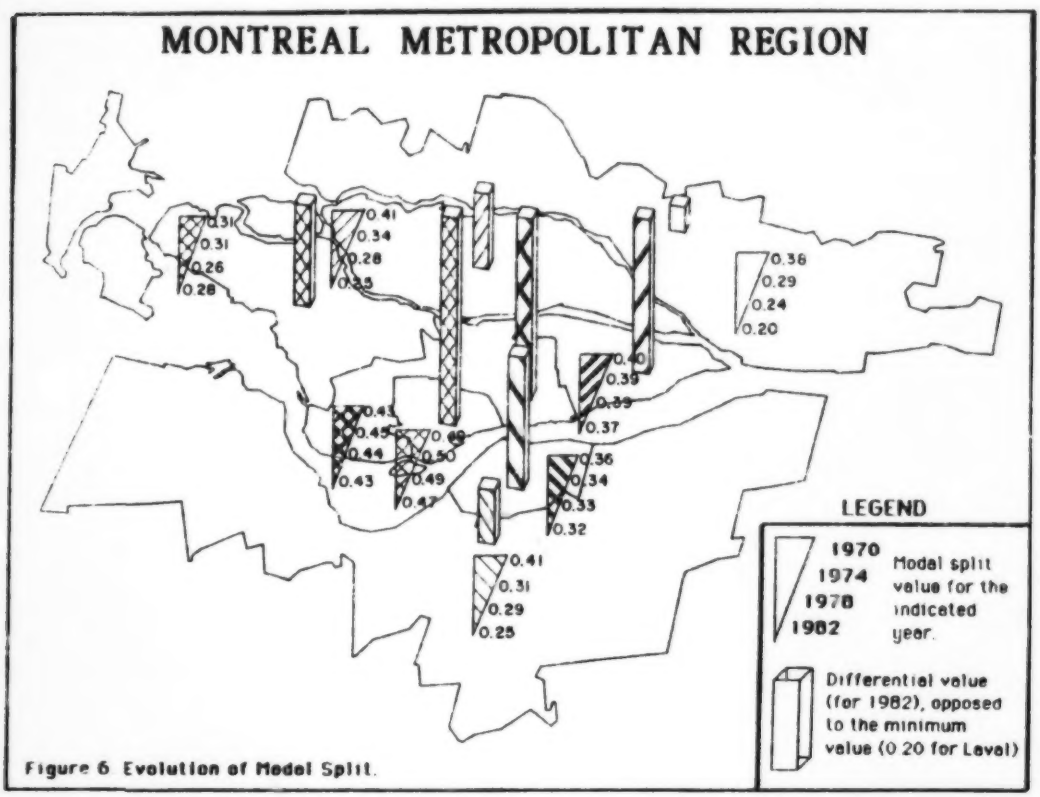


Figure 6 Evolution of Modal Split.

DISAGGREGATE ANALYSES ACCORDING TO DEMOGRAPHIC CATEGORY

For operational reasons --as demand modeling has to be based on normalized, dependable and widely available data--, the following analyses are carried out according to standard demographic cohorts (5-year groups, by sex); census and planning organizations (StatCan, B.S.Q., O.P.D.Q.) frequently produce demographic forecasts (3) in this format, for school, health, welfare and other socio-economic planning purposes. For the rest of the analysis, we drop the 1970 survey data, because of its incompatibility with the 5-year cohort format.

Demographic distribution

The aging of the Montreal population is clearly illustrated by the graph (Figure 7) of demographic distribution. The importance of age cohorts 5-9, 10-14, 15-19 and 45-49 is rapidly decreasing for both sexes, compensated largely by the gains of the 25-39 and 55+ groups; sex distribution remains relatively equal with the exception of senior citizen's group, where the effect of the longer life expectancy of women is obviously preponderant.

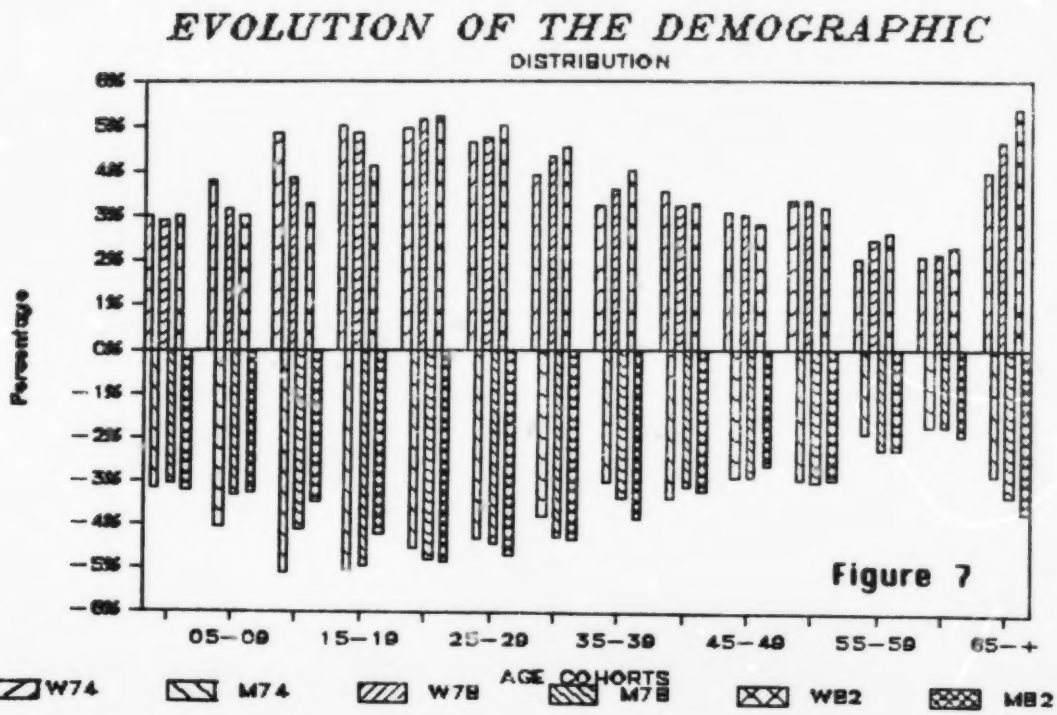


Figure 7

Population mobility

Personal mobility may be examined in two interesting ways: active (working) and non-mobile (no trip) persons. The combination of economic recession and social factors have produced the following trends: absolute decrease in the number of active men, and increased participation of women in the workforce (Fig. 8a). Despite a higher level of unemployment which, incidentally, has had a diminishing effect on the relative workforce participation of men between 1974 and 1982, the 25-44 female group has steadily increased its presence (fig. 8b). In 1974, 52% of the male population was making one work trip compared with 49% in 1982; the ratio "active men/women" dropped from 1.90 in 74 to 1.61 in 82, demonstrating a strong evolution in social roles. A similar phenomenon can be observed in the non-mobile population, which is some sort of female "specialty" (30% vs 10% for medium age groups); figure 9a illustrates an absolute decrease in non-mobility, due almost exclusively to the steady and continuous increase in mobility of women of more than 25 years old (fig. 9b). In summary, it can be said that women, contrary to men, have gained some "spatial freedom"; the young and the old of both sexes have also followed this same trend.

URBAN TRANSPORTATION MARKET SEGMENTS

The MUCTC regional Origin-Destination surveys consider, for each trip made between a pair of zones, the specification of the mode (car driver, car passenger, transit --train, metro, regular bus, school and other bus--, walking, others) and the purpose (work, study, shopping, leisure, others, home return). These data, which are more extensively analyzed in the work of Girard (6), enable us to identify some interesting facts about different segments of the urban transport market:

- *for the total number of trips*, the 15-34 group, representing 37% of the population, manages 42% of all trips: highest weight combined with the highest trip rate;
- *for walking trips*, globally, there is a steep drop from 1970 to 1978 (25% to 15%) and the level is maintained in 1982 at 15.7%. In 1982, women walked more than men (17.7% vs 13.9%), but the difference is much less noticeable that it was in 1974 (24.4% vs 17.7%);
- *for transit trips*, the expansion of networks is reflected by a steady increase in demand between 1970 and 1982, giving 1 355 000 trips on an average weekday. We observe different types of transit usage behaviour between men and women of the same category --working and non-working persons by age class, 1982-- (fig. 10a): with the exception of students, the contribution of women to transit usage is always more significant and, interestingly, is double the male contribution for the 15-24 age group of working persons. Figure 10b expresses the trends in modal split for each sex and age group: in 1982, transit is used for 28% of the trips made by women against 19% for men; new fare schemes (subsidized monthly passes offered in 1982) have increased transit usage for the

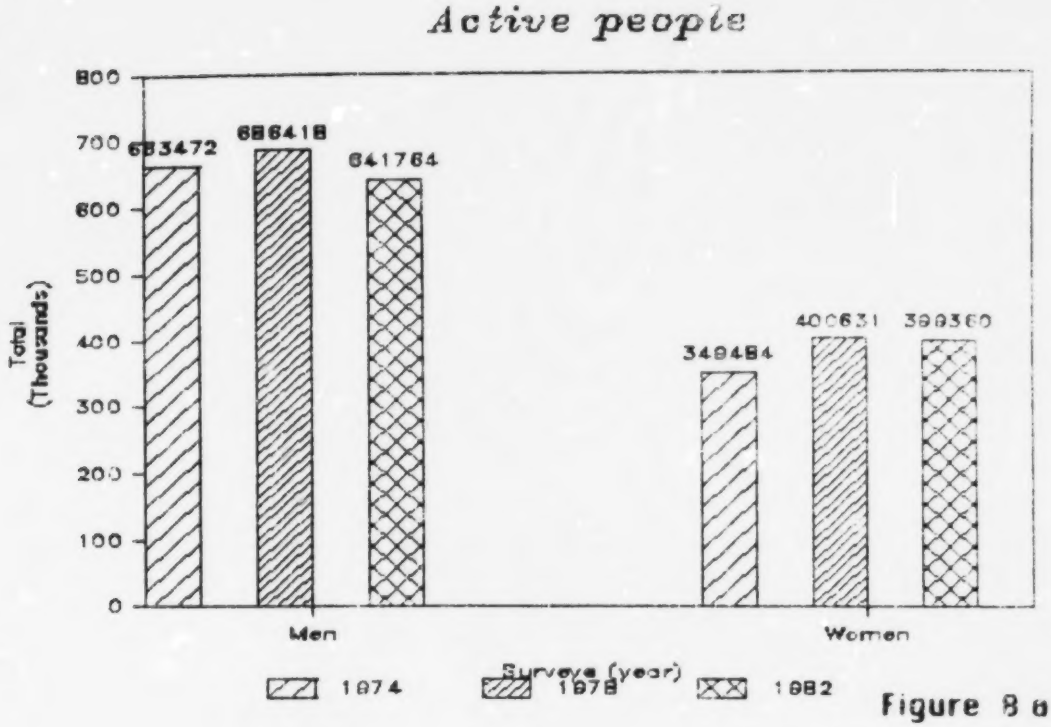


Figure 8 a

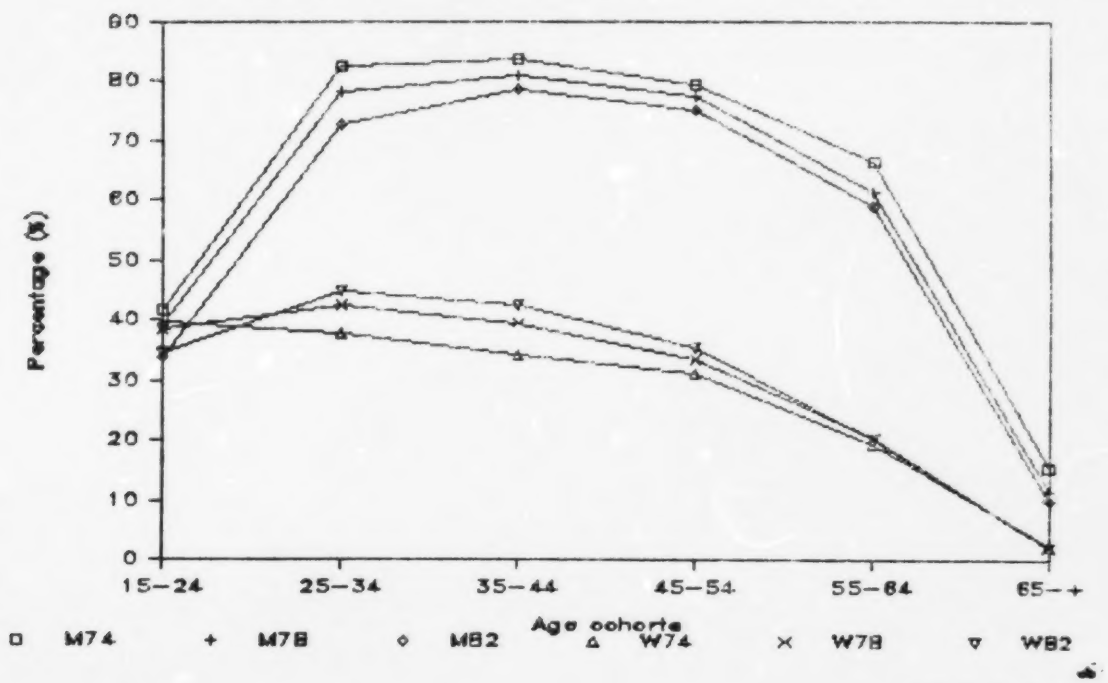


Figure 8 b

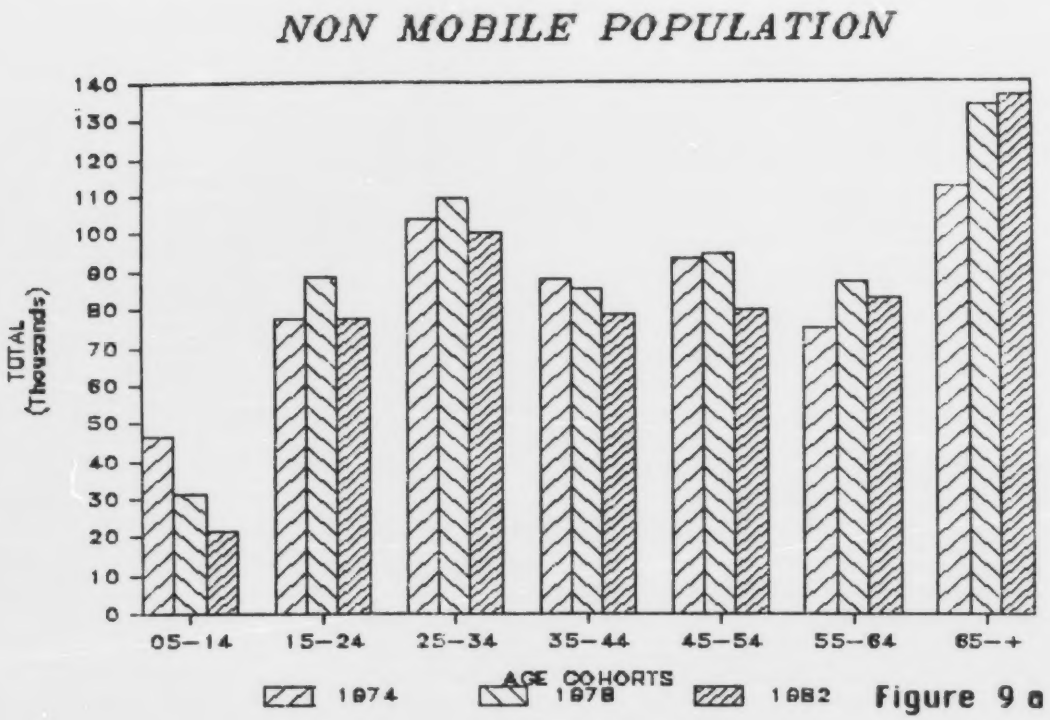


Figure 9 a

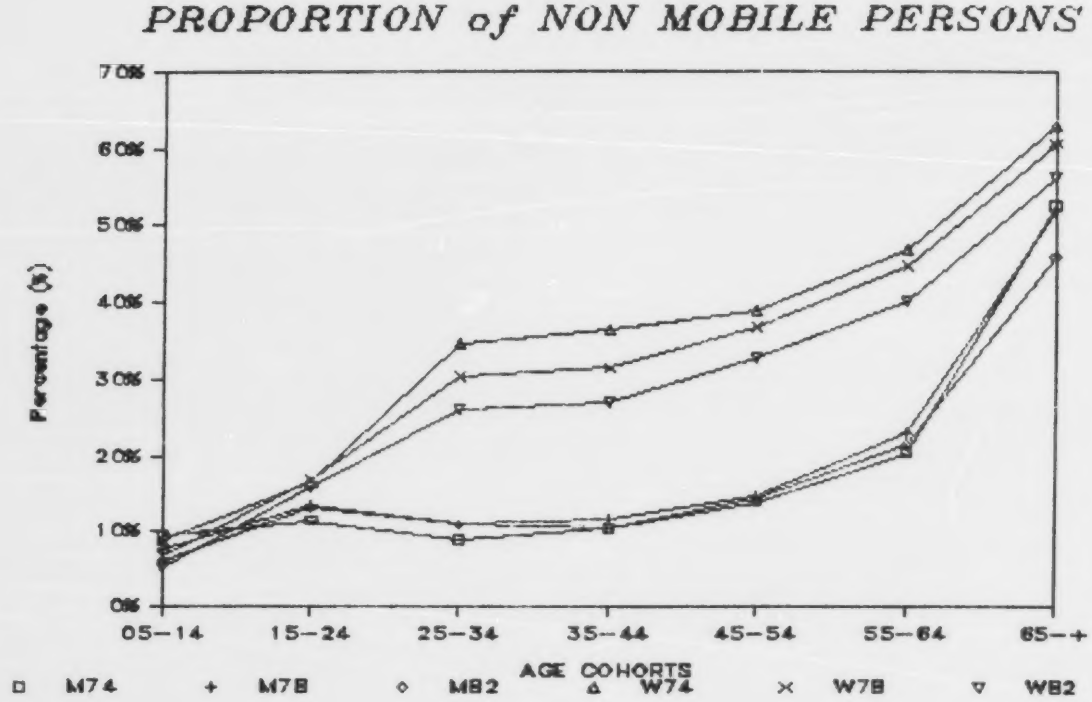


Figure 9 b

young and the old, but for the active classes -- 35-64 age groups of men and women-- there has been steady decline in the relative importance of transit from 1974 to 1982.

- *car usage* is ever increasing. The proportion of male drivers goes from 78%(74) to 74%(78) to 70%(82); the proportion female car passengers remains constant at the 70% level. Women used the car for 46% of their trips in 1982, compared with 36% in 1974; peak usage (68.5%) is observed for the 35-44 age group. Men used the car for 60.6% of their trips in 1982, which is same value as in 1978; peak usage for the 35-44 age group is 83%; for men in 1982, car usage decreased 5 percentage points for the 25-34 age group while the 55-64 age group progressed 7 percentage points as compared with 1974. There have been enormous gains for mature women in their accessibility to car transportation; from 1974 to 1982, car usage progressed respectively from 57% to 69%, 47% to 58% and 37% to 49% for the female 35-44, 45-54 and 55-64 age groups.

- *the proportion of work trips* has slowly decreased from 1974 to 1982; in 82, work trips represented 37% of all trips, 62% of these made by men. Men of the 45-54 group devote 68% of their trips to work, in comparison to 42% for women of the 25-34 group.

- *study trips* constitute the only category without sex differentiation; the majority of trips are made by the young: 57% (5-14) and 35% (15-24); these represent respectively 85% and 38% of all trips for each group. Globally, for demographic reasons, the weight of this market segment (23% in 1982) is steadily decreasing.

- *shopping trips* make up 15% of all trips, 33% of these made by men; this proportion has increased since 1970, especially among men. In absolute terms, the 25-34 age group of women is the most important segment (14% of all the shopping trips). Worthy to mention is the relative importance of shopping trips among senior citizens (40% for men, 51% for women).

- *leisure and other purpose trips* represent respectively 10% and 17% of all trips, with an upward trend; larger leisure consumers come from the 15-24 age group of men, while both sexes of the 25-34 age group are the most important consumers of other purpose trips.

EVOLUTION OF TRIP RATES ACCORDING TO SEX and AGE

The following table (Table 1) provides a detailed and complete quantitative summary of demographic trends and related evolution in mobility for men and women from 1974 to 1982. Column 2 gives the relative weight (%) of every age stratum in the 1982 population: note the massive importance of the 15-39 age group. Column 3 exhibits the percentage increase of every cohort from '74 to '82, demonstrating the strong growth of the 30-39 and 65 + groups and the steep decline of the 5-19 group. Columns 4, 5 and 6 show cohort trip rates with a steady increase of mobility from '74 to '82 and clear sex differentiation in travel behaviour, except for the young (5-19 group). The last columns show the evolution of transit usage (trip rate per capita): increase for the young and the old,

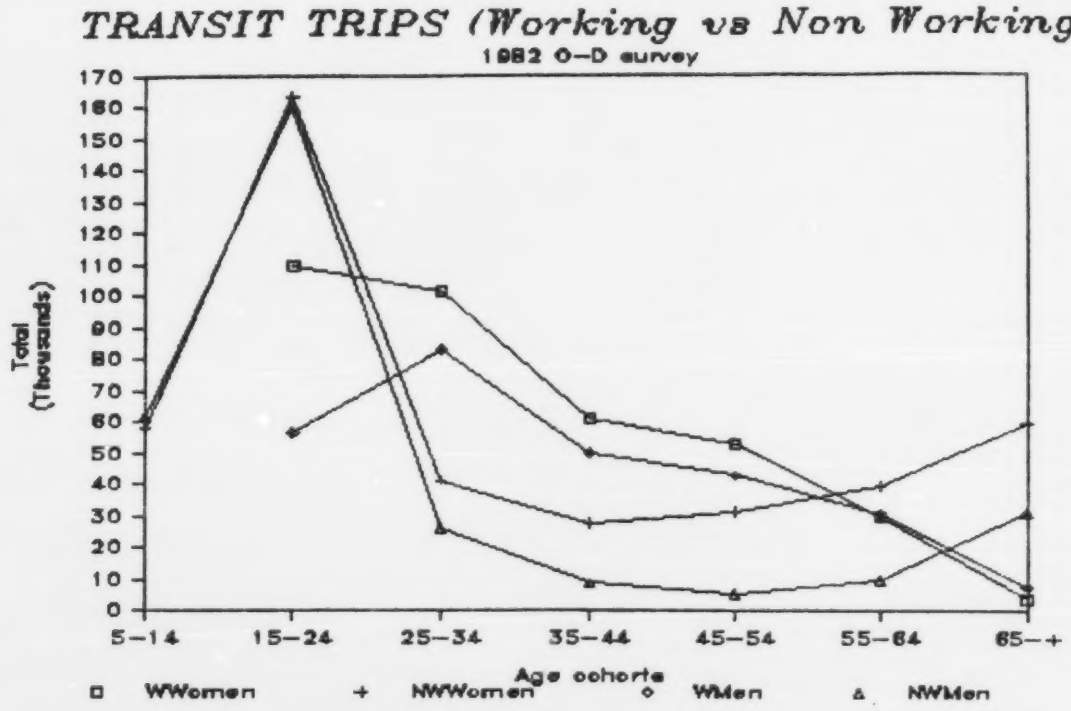


Figure 10 a

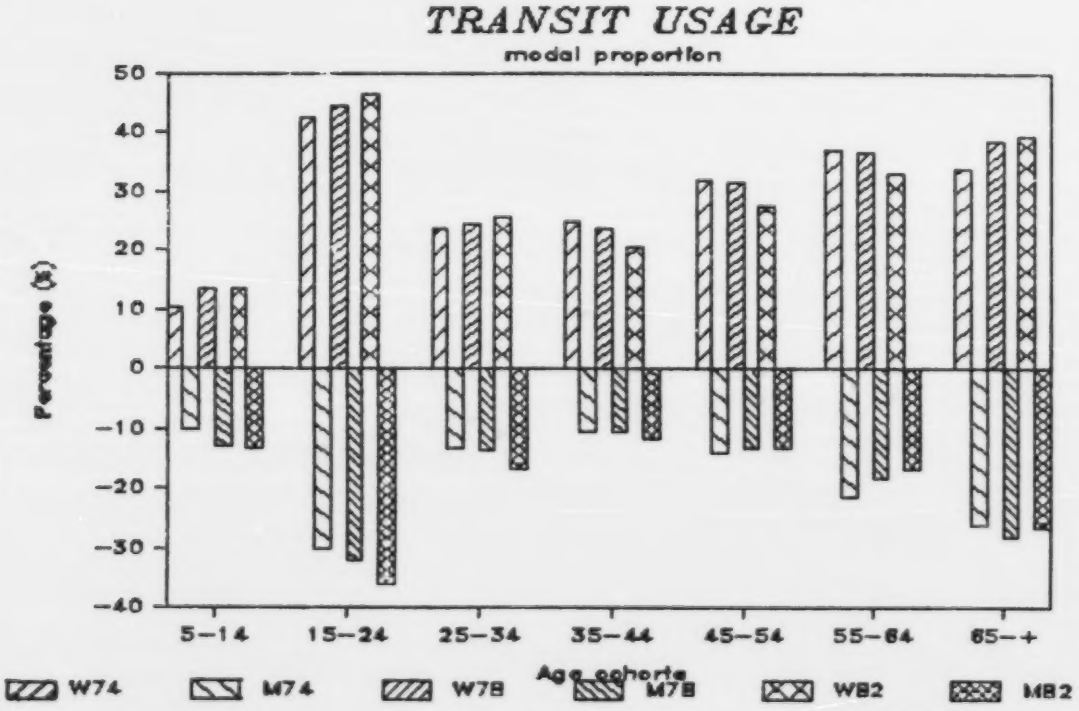


Figure 10 b

TABLE 1. TOTAL and TRANSIT trip rates ('74 to '82)

	1982 POPU %	74-82 increase	TOTAL trip rate 1974	1978	1982	TRANSIT trip rate 1974	1978	1982
MEN								
5- 9	3.49	-16.70	1.81	1.91	2.10	0.06	0.07	0.08
10-14	3.72	-29.36	2.00	2.10	2.22	0.36	0.46	0.54
15-19	4.45	-14.26	2.06	2.09	2.23	0.88	0.93	1.11
20-24	5.15	10.60	2.20	2.15	2.33	0.66	0.61	0.74
25-29	4.99	12.09	2.31	2.34	2.49	0.40	0.41	0.50
30-34	4.60	18.28	2.29	2.33	2.52	0.32	0.31	0.43
35-39	4.11	32.41	2.24	2.30	2.53	0.29	0.27	0.35
40-44	3.43	-0.87	2.16	2.23	2.46	0.31	0.30	0.31
45-49	2.81	-6.40	2.10	2.20	2.38	0.32	0.31	0.34
50-54	3.15	2.80	2.02	2.05	2.20	0.38	0.35	0.33
55-59	2.41	21.22	1.96	1.94	2.08	0.45	0.38	0.36
60-64	2.05	12.48	1.72	1.71	1.93	0.47	0.38	0.38
65-69	1.62	27.83	1.27	1.32	1.60	0.35	0.36	0.39
70-74	1.16	31.83	1.03	1.17	1.38	0.30	0.38	0.41
75 +	1.08	40.64	0.76	0.76	1.04	0.24	0.24	0.36
WOMEN								
5- 9	3.23	-17.80	1.81	1.93	2.13	0.06	0.07	0.07
10-14	3.48	-30.19	2.00	2.08	2.21	0.38	0.46	0.56
15-19	4.36	-15.82	2.01	2.05	2.18	1.10	1.13	1.26
20-24	5.51	8.49	1.87	1.97	2.13	0.91	0.92	1.01
25-29	5.35	12.00	1.63	1.83	2.04	0.50	0.57	0.63
30-34	4.84	20.03	1.60	1.76	2.04	0.38	0.40	0.49
35-39	4.33	30.68	1.58	1.82	2.12	0.44	0.44	0.44
40-44	3.50	-4.75	1.52	1.71	1.98	0.47	0.49	0.48
45-49	2.96	-6.61	1.46	1.59	1.83	0.52	0.51	0.52
50-54	3.37	-2.70	1.40	1.52	1.68	0.54	0.56	0.53
55-59	2.75	33.18	1.29	1.35	1.54	0.55	0.50	0.52
60-64	2.41	11.24	1.16	1.21	1.44	0.47	0.51	0.52
65-69	2.23	31.91	1.03	1.09	1.33	0.40	0.46	0.56
70-74	1.61	36.28	0.83	0.92	1.06	0.31	0.38	0.47
75 +	1.85	50.23	0.51	0.58	0.69	0.16	0.22	0.27
TOTAL								
men	48.23	2.60	2.03	2.07	2.24	0.42	0.42	0.48
women	51.77	3.69	1.60	1.70	1.88	0.53	0.56	0.60
ALL	100.00	3.16	1.81	1.88	2.06	0.47	0.49	0.54

leveling off (modal split decline) for the 40-64 group, transit being largely favoured by women. Lesser mobility of women combined with stronger transit usage means significant differences compared to men concerning modal choice, as previously illustrated.

NON UNIFORMITY OF TRAVEL BEHAVIOUR OVER SPACE

In a metropolitan region, urban sprawl is also an ever-present factor and it is known that urban development does not result in a very homogeneous spatial distribution of socio-economic and demographic characteristics. These factors have profound influence on travel behaviour.

To illustrate the multidimensionality of these combined phenomena, the study territory has been decomposed, in a very subjective way, into 8 large subregions, primarily radioconcentric around the Montreal Central Business District --to follow crudely historical demographic development--. The map in figure 1 shows a large CBD, a CBD periphery, an AFFLUENT sector close to the CBD and 5 other regions which may be considered as suburbs: EAST of Montreal island, WEST of Montreal island, city of LAVAL (north), SOUTH shore and NORTH shore regions. The MUCTC provides service for the first 5 subregions, while two medium-size transit authorities serve the others.

The most relevant variables for explaining aggregate mobility are presented in table 2: household revenue, evolution of the number of households, family size, population, average age and related trip rates. The figures are self-explanatory concerning the relative growth and composition of urban and suburban sectors. Development is observable only outside the Montreal island, with a younger population. Family size has decreased everywhere from 1974 to 1982; the average of a sector appears to be inversely related to the area density. The same is true for age. A similar correlation exists between location at the proximity of CBD and transit usage, reflecting the combined effect of area density, higher transit supply and lower revenue.

A very strong relationship emerges between, at aggregate level, revenue and mobility expressed in terms of total (all modes) trip rate per capita. Transit usage seems to be more affected by supply.

For each subregion, much more detailed data analyses have been carried out confirming the major aforementioned trends, in behaviour differentiation based on sex and age cohorts. The same transit usage patterns are observed with more or less amplification according to spatial location (proximity to CBD and transit supply).

TABLE 2. MOBILITY STATISTICS -- SUBREGIONS

	1982 HH REVENUE index	HOUSEHOLD	pers /hh	POPULATION 5 + over	avg AGE	TOTAL trip rate	TRANSIT trip rate
METROPOLITAN							
1982	1.00	1074909	2.69	2733981	35.6	2.06	0.54
1978		1031975	2.86	2777165	34.6	1.88	0.49
1974		897081	3.15	2650281	33.1	1.81	0.47
CBD							
1982	0.84	429627	2.31	945210	38.5	2.02	0.75
1978		442219	2.50	1058049	37.5	1.84	0.68
1974		400701	2.81	1072669	35.9	1.77	0.60
near CBD							
1982	0.98	154881	2.61	392309	37	2.06	0.67
1978		153693	2.84	413978	35.5	1.90	0.61
1974		144258	3.12	424551	33.1	1.84	0.57
AFFLUENT							
1982	1.39	42818	2.57	109135	39.3	2.29	0.65
1978		39425	2.76	103951	37.6	2.00	0.61
1974		37560	3.02	108067	35.6	1.94	0.58
EAST							
1982	0.92	54967	2.94	144996	34.4	1.99	0.58
1978		50327	3.10	147049	32.8	1.86	0.55
1974		43357	3.44	139461	30.3	1.77	0.51
WEST							
1982	1.31	60175	2.99	169569	33.9	2.25	0.38
1978		54785	3.20	162519	32.4	2.09	0.16
1974		49473	3.50	160385	30.6	1.99	0.24
LAVAL							
1982	1.11	90908	3.03	261537	33.6	2.03	0.46
1978		75636	3.35	236682	31.7	1.88	0.41
1974		66680	3.67	228040	30.1	1.82	0.42
SOUTHshore							
1982	1.16	142789	3.16	421649	31.9	2.09	0.33
1978		127988	3.32	389287	30.8	1.91	0.28
1974		97904	3.62	323848	29.5	1.84	0.25
NORTHshore							
1982	1.10	93704	3.21	275492	31.6	2.00	0.11
1978		82264	3.33	247997	30.5	1.83	0.10
1974		54763	3.71	185054	29.7	1.74	0.11

FORECASTING TRANSIT USAGE

Our analysis has dealt with data categorization (sex, age cohorts), and temporal ('74, '78, '82 surveys) and spatial (8 subregions) evolution. For forecasting purposes, we have confirmed (--following the reflections of Supernak (10), Macke (7) and Ben-Akiva (1)--), the slim potential for temporal and spatial transferability of a standard trip rate model. But, because of the built-in coherence between age cohorts and equal-time-interval surveys, we tried the following experiment: we used a Box & Jenkins (2) ARIMA (AutoRegressive Integrated Moving Average) time-series model to forecast transit usage in the future (say, 1986, 1990). A model is developed for each subregion and estimates are made for men and women on absolute (total number of transit trips) or rate (transit trip rates) variables which are, in the last case, ultimately combined with readily available demographic forecasts.

Data experiments, with the SAS (8,9) package, have confirmed homogeneity and non-stationarity for all the models tested: the models are seen to be seasonal, differentiated and autoregressive. The general formula is:

$$(1 - B^{s+1})\ (1 - B^{s})\ X_t = a_t$$

or

$$X_t = a_t + X_{t-s} + X_{t-s-1} - X_{t-2s-1}$$

where

- X_t : transit trips made by cohort-time t
- a_t : random noise
- B : backward moving operator ($B^{16} * X_t = X_{t-16}$)
- s : number of seasons per cycle

Figure 11 illustrates the complete set-up with data plotted for the 3 surveys ('74, '78, '82) and forecasts obtained for '82, '86 and '90. Comparison of projected and observed values is possible for 1982, and the confidence interval (at 95% level) is plotted. Table 3 shows aggregate results for the metropolitan region and the 8 subregions. Except for some irregular data, the error magnitude seems reasonable; moreover, detailed forecasts (not illustrated here), for every region-age-sex group, are obtained by the method.

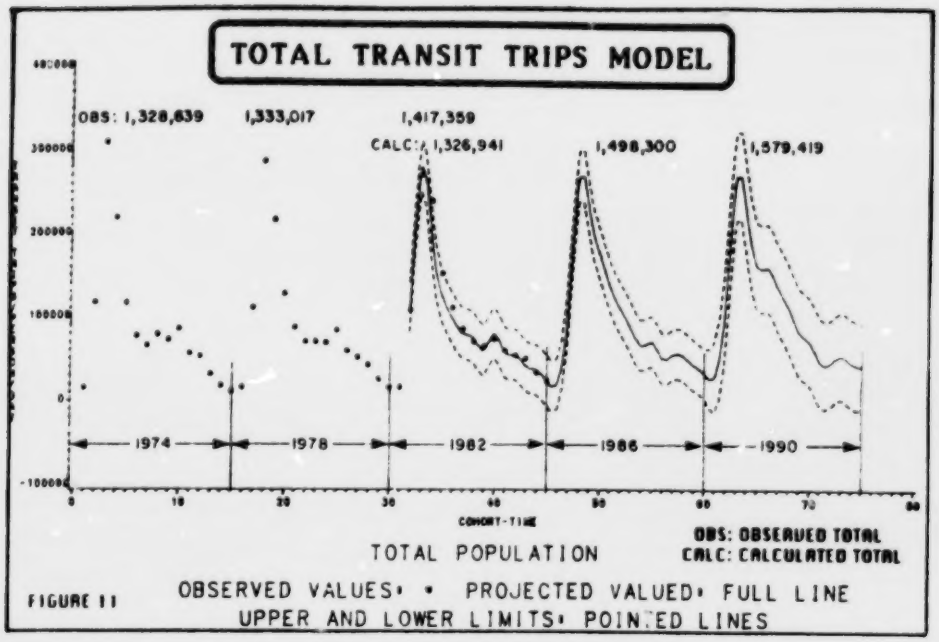


Figure 11. Transit usage forecasts (analog time-series)

TABLE 3. Forecasts of transit usage in '86 and 90

transit trips	OBSERVED DATA 1974	1978	1982	PROJECTED DATA 1982	1986	1990
CBD	650493	711463	704748	769949	695020	688882
CBD peri	243141	252860	260825	262173	267729	272901
EAST sub	72339	81228	84014	89414	86289	89014
WEST sub	42964	31340*	59239	18853	88064	116199
SOUTHsho	103472	95264	119964	85213	144577	168805
LAVAL	125980	68310*	87694	9662	107166	126227
NORTHsho	26480	25910	28860	24384	31598	34060
AFFLUENT	62245	63766	70824	63142	78199	85282
METROPOL	1328639	1333017	1417359	1326941	1498300	1579419

*: peculiar conditions

CONCLUSIONS

This paper describes results from an extensive analysis of a unique set of data: four four-year-interval O-D surveys for the Montreal metropolitan area. Many factors influencing personal urban mobility have been confirmed:

- the following demographic factors affecting urban transit have changed greatly over the 1970 decade: age composition, population sprawl into suburban areas, growing number of households, continuous increase in women's participation in the workforce;

- household size, population aging, car ownership and the evolution in individual mobility for certain groups seem to be the most significant variables for explaining modal split;

- travel behaviour, formulated in terms of trip rate or transit usage, is a non-stationary process which varies in time and space.

Facts and figures from the Montreal case suggest a number of things for specific conviction about serious demand modeling: forecasting public tranport usage for medium or long-term horizons (5 to 15 years) needs a modeling framework which reflects and reacts to observed socio-demographic trends. To be fully operational, the specification of the model has to be based on already available data (demographic forecasts, often developed for social services --health and education--), with a categorization into "cohorts" (sex,age group).

Analyses using spatial, temporal, sex and age differentiations have many advantages when applied to historical (and) demographic data. In particular, they enable a transportation analyst to examine more subtle problems; from this perspective, three topics were addressed:

a) an analysis of the evolution of specific mobility phenomena due to changes in employment (economic recession, effects on the young, increase in service jobs, female participation), changes in the system of values (increase in female mobility, especially for the elderly); the groups of people mentioned are subjected to new influences, which will greatly affect transit usage in the future;

b) the use of a time-series forecasting model (Box-Jenkins ARIMA procedure) to make combined predictions of demographic and mobility impacts on urban transport modes;

c) detailed interpretation of the results and their consequences on the estimation of public transport usage (and expected revenue) in the future, based on the spatial distribution of the demographic groups in a region.

The application of the forecasting model to the Montreal Metropolitan area, for 1986 and 1990, produced interesting results... and may suggest some marketing strategies for public transportation.

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